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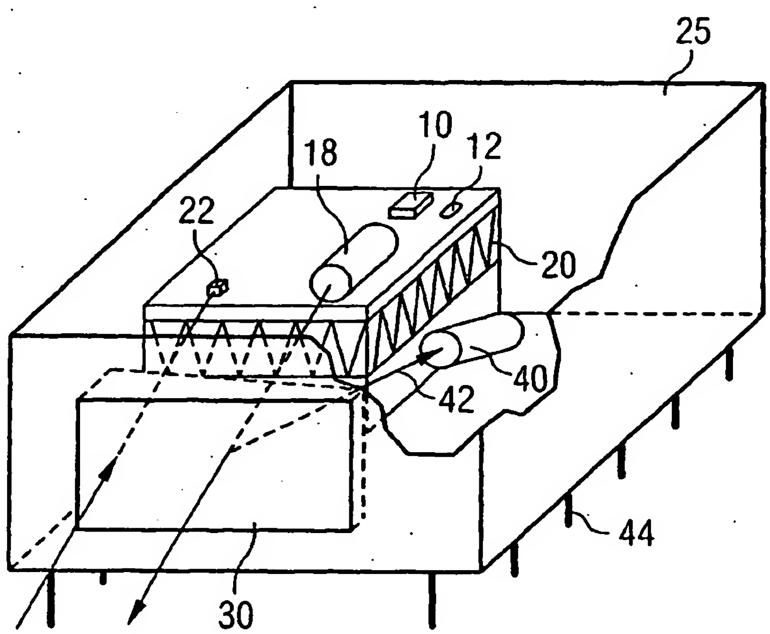
[Continued on next page]

(54) Title: A WAVELENGTH STABLILISED LASER SOURCE



WO 02/073757 A2

(57) **Abstract:** There is provided an integrated wavelength-stabilised laser source comprising: a laser diode; a temperature-stabilising heat pump in thermal communication with the laser diode; and at least one detector, encapsulated within a hermetically sealed package comprising a window for passing light from the laser diode to the exterior of the package.

A WAVELENGTH STABILISED LASER SOURCE

The present invention relates to laser or light sources, in particular, laser sources of stabilised wavelength.

Throughout this document, the control of wavelengths will be discussed. In this context, use of the term 'wavelength' assumes a known transmission medium, in accordance with standard terminology in the art. Furthermore, the invention will be described with reference to laser light produced by a laser diode. The invention may, however, be applied in a corresponding fashion to other light sources.

Many applications require a laser or light source providing a stabilised wavelength. An example is a gas detection instrument, in which a laser or light source must be provided, and controlled to provide a stable wavelength, corresponding to an absorption line of the spectrum of the gas to be detected. If the provided light is absorbed, the gas is deemed to be present to an extent commensurate with the proportion of light absorbed. If the provided light is not absorbed, the gas is deemed not to be present. Various levels of absorption may be correlated to various densities of target gas and optical path lengths therein.

The present invention will be particularly described with reference to gas detection instruments, although the present invention is also applicable to other applications of stabilised wavelength light or laser sources, including applications in the telecommunications industry where precise tuning to specific communications wavelengths is important. For example, wavelength references for optical test equipment such as spectrum analysers, optical transmission/receiver

hermetically sealed package comprising a window for passing light from the laser diode to the exterior of the package.

The heat pump may be operable to adjust the operating temperature of the laser diode, thereby adjusting the wavelength of light emitted by the laser diode.

The source may further comprise a temperature sensor arranged to provide primary control of the operation of the heat pump.

The at least one detector comprises a monitor detector, positioned to receive a portion of laser light emitted by the laser diode.

A surface of the window may be arranged to reflect the portion of light emitted by the laser diode to the monitor detector.

The monitor detector may be arranged to provide a control signal for controlling the wavelength of light produced by the laser diode.

The hermetically sealed package may contain a gas sample, said gas having an absorption line for use by the monitor detector for measuring the wavelength of light emitted by the laser diode. In this case, the interior of the hermetically sealed package may be substantially filled with a gas sample.

The monitor detector may comprise a light sensor exposed to the interior of the hermetically sealed package. Alternatively, the monitor detector may comprise a light sensor and a gas sample, enclosed within an enclosure.

Secondary control of the heat pump is preferably provided, in accordance with an output of the monitor detector.

The control signal from the monitor detector may be arranged to control the operation of the heat pump, thereby adjusting the wavelength of light emitted by the laser diode by adjusting the operating temperature of the laser diode. Alternatively, or in addition,

The present invention employs a novel approach to packaging the light or laser source. The techniques used are similar to techniques employed in the telecommunications industry and provide an integrated approach that offers significant advantages over known techniques which involve assembling the required components individually into an instrument. The known techniques involve difficulties including those arising from moisture ingress and condensation.

Fig. 1 shows a light or laser source according to an embodiment of the present invention. Laser diode 10 is placed in thermal contact with a Peltier heat pump 20 and is provided with a drive current to produce laser light. A focusing lens 18 is provided to focus the light emitted from laser diode 10. A signal detector 22 is also provided, for detecting incident light. These elements are all encased within a housing 25. A window 30, transparent to the wavelengths emitted by laser diode 10, is provided in a part of the housing 25, to allow light from the laser diode to leave the housing, after passing through focusing lens 18, and to allow incident light to enter the housing to be detected by signal detector 22. The housing 25 is a hermetically sealed enclosure, preferably similar to those currently used in the telecommunication industry, and manufactured according to existing and established practices in that industry.

A temperature sensor 12 is provided, mounted on heat pump 20, preferably in the general vicinity of the laser diode 10. In certain embodiments of the invention, the temperature sensor is a platinum resistance thermometer, but other temperature sensitive devices of suitable size and sensitivity could be used. The temperature sensor provides an output signal to a temperature control means (not shown),

the gas sample, C is the gas concentration, d is the path length through the gas and s is the absorption constant for the gas.

The integrated light or laser source of the present invention is suitable for incorporation into a gas monitor product for use in telecommunications equipment. For the successful manufacture of a gas monitor product, the output wavelength of the laser diode 10 must be precisely controlled to coincide with an absorption line of the spectrum of a target (measured) gas. The laser diode 10 must therefore be temperature stabilised very precisely (typically to 0.1°C). In the illustrated embodiment of the present invention, thermal control of the laser diode is achieved by use of a Peltier heat pump 20 that can be used to either cool or heat the laser diode 10 as required, depending on an ambient temperature.

Fig. 2 shows a second embodiment of the present invention in which a monitor detector 40 is provided within the housing 25. Features corresponding to those discussed with reference to Fig. 1 carry corresponding reference numerals. The output of this detector provides a means to positively and reliably identify the operating wavelength of the laser which can be controlled in accordance with the output of monitor detector 40, by varying the operating temperature of the laser diode 10, or the drive current applied, or both, whereby precise control of the laser wavelength can be produced. This enables a more stable wavelength to be produced than would be possible with the embodiment of Fig. 1.

In operation, the laser diode 10 provides light which is focused through lens 18 and transmitted out through the window 30. Because of a difference in refractive indices between the material of the window 30

sealed enclosure. Such monitor detector enclosure preferably contains a sample of a gas whose absorption line is to be used for tuning the wavelength emitted by the laser diode. Such gas is not necessarily the same as a gas which is to be detected by a gas detector incorporating the laser source, but such gas should be chosen to have an absorption line in the wavelength range of interest. The absorption line is preferably chosen to be as fine as possible.

In an alternative embodiment, the monitor detector 40 comprises a light sensor, which may be in the form of an integrated circuit die which is exposed to the interior of the hermetically sealed housing 25. The volume inside the package may be filled with a gas whose absorption line is to be used for tuning the wavelength emitted by the laser diode. Such gas is not necessarily the same as a gas which is to be detected by a gas detector incorporating the laser source, but such gas should be chosen to have an absorption line in the wavelength range of interest. The absorption line is preferably chosen to be as fine as possible.

Primary tuning of the laser diode is achieved by changing the temperature of the diode according to the information derived from the temperature monitor 12 within the package. This is sufficient to allow the wavelength emitted by the laser diode to be 'tuned' to the vicinity of an absorption line. While temperature monitor 12 provides information for primary temperature control, the monitor detector 40 monitors the accuracy of the wavelength emitted by the diode very precisely, by comparison with an absorption line of a reference gas. The monitor detector 40 may comprise a light sensor exposed to the interior of the housing 25. The monitor may alternatively comprise a transparent enclosure, itself containing a light sensor, the enclosure being mounted

several microseconds, whereas a temperature controlled wavelength change may take several milliseconds.

In further embodiments, the secondary tuning may be achieved by a combination of controlling the temperature of the laser diode and by controlling the current through it. For example, in order to produce a desired wavelength, the heat pump 20 may be controlled to heat the laser diode 10 to a corresponding temperature T as indicated on the datasheet of the laser diode 10, and as measured by temperature sensor 12. The laser diode will be supplied with a nominal current such as 100mA, and a wavelength in the vicinity of the required wavelength will be produced. The current supplied to the laser diode may then be scanned , for example, between 50mA and 150mA while the monitor detector 40 monitors the resulting wavelength. The required wavelength may be achieved, for example, at a current of 145mA. The laser diode may then be operated at the temperature T and a current of 145mA. This will provide the required wavelength, but will consume excess power, and will only leave 5mA of drive current available to compensate future drift in the wavelength produced. Preferably, the heat pump is then controlled to heat or cool the laser diode as appropriate, with the current supplied to the laser diode being correspondingly reduced until it returns to the nominal value (in this example, 100mA), with the laser diode operating at a different temperature, $T + \delta T$. Such compound secondary tuning has the advantage that current control may be used for fast response and to maintain constant wavelength even through short term fluctuations, while temperature control allows wider overall range of wavelengths and can re-centre the range of current control to ensure that current control is always available.

with reference to Fig. 2, a portion 42 of the light emitted by laser diode 10 through focusing lens 18 is reflected from a surface of the window 30. This portion 42 is received by monitor detector 40, which contains a light detecting element. A sample of a reference gas is provided, within the monitor detector and/or filling the cavity within the housing 25. The detecting element may be used as discussed with reference to Fig. 2 in order to adjust the wavelength of the light provided by laser diode 10 to correspond to an absorption line of the spectrum of the gas sample. By controlling the heat pump 20, the output wavelength from laser diode 10 may be very accurately controlled, providing a light source of very stable wavelength. Such source may find applications in gas detectors and communications equipment, for example.

The laser or light sources according to the present invention, as described, are mounted in a hermetically sealed enclosure, similar to housings commonly used in the telecommunications industry. The housing ensures that the devices are kept clean and dry which is vital for reliable operation (especially when the Peltier is actively cooling the package below ambient temperature). The housing may be evacuated, or may be filled with a dry inert gas which has no spectral absorption lines in the wavelength range of operation. The various components within the housing need to be kept thermally isolated from one another, and a vacuum or a dry gas is preferably used to fill the housing although a transparent liquid or solid could be used, preferably one with a low thermal conductivity.

In each embodiment, pins 44 allow external connections to be made to the Peltier heat pump, the laser diode, the detectors and/or any other apparatus within the housing 25. For example, control circuitry

communications signalling function. Secondary tuning is preferably not provided by temperature alone, as the reaction time may be too slow to provide the required accuracy in wavelength.

In the field of gas measurement, Primary control of the wavelength of the emitted light may be exercised according to the temperature sensor 12. Secondary control may be exercised by adjusting the temperature of the laser diode according to the output of the monitor detector. For example, a required wavelength may be obtained by primary control of the temperature of the laser diode, with secondary control initially being provided by controlling the current through the laser diode. The temperature may then be adjusted to allow the drive current to return to its nominal value. The required wavelength is then provided by suitable selection of the operating temperature of the laser diode. The drive current may then be adjusted to provide a wavelength offset from the required value. For example, this could be to detect an absorption line other than the absorption line used by the monitor detector. This may be an absorption line of a gas other than the reference gas. The drive current may be progressively adjusted to provide a "sweep" in wavelength across a certain range in the general vicinity of the required wavelength. Measurements of the intensity of light received in the sensor 22 are taken, and correlated against the wavelength emitted at that time. By taking a sequence of measurements of intensity readings against wavelength, a shape of an absorption line in a monitored gas may be measured, allowing the density and presence of a corresponding gas to be identified. By providing sufficient coverage in the wavelength sweep, the presence of two or more gases can be detected, for example, methane and ethane. The wavelength produced by the laser diode should be periodically

In further alternative embodiments, a laser diode may be used which is active in two directions. Light emitted in one direction may be directed through the window 30, while light emitted in the other direction may be directed onto a monitor detector. In such embodiments, the monitor detector could be placed behind the laser diode, as it will not be necessary to obtain a reflection from the window. An antireflective coating may then be applied to at least one surface of the window in order to reduce reflections of the emitted light, thereby reducing any interference effects caused by the passage of the light through the window.

6. A source according to claim 4 or claim 5 wherein the monitor detector is arranged to provide a control signal for controlling the wavelength of light produced by the laser diode.

7. A source according to any of claims 4-6, wherein the hermetically sealed package contains a gas sample, said gas having an absorption line for use by the monitor detector for measuring the wavelength of light emitted by the laser diode.

8. A source according to claim 7 wherein the interior of the hermetically sealed package is substantially filled with a gas sample.

9. A source according to any of claims 4-8 wherein the monitor detector comprises a light sensor exposed to the interior of the hermetically sealed package (25).

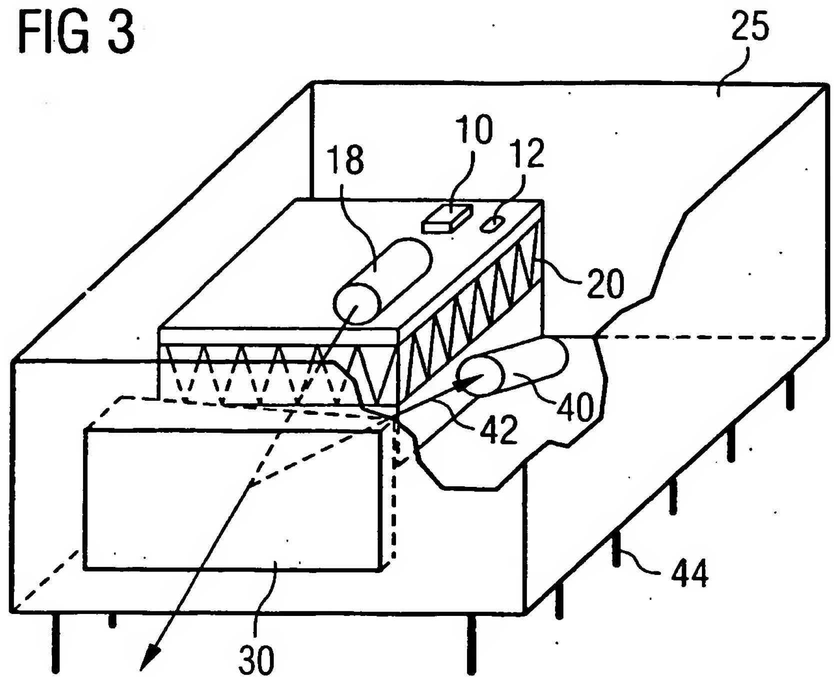
10. A source according to any of claims 4-8 wherein the monitor detector comprises a light sensor and a gas sample, enclosed within an enclosure.

11. A source according to any of claims 6-10 wherein the control signal from the monitor detector is arranged to control the operation of the heat pump, thereby adjusting the wavelength of light emitted by the laser diode by adjusting the operating temperature of the laser diode.

12. A source according to any of claims 6-11 wherein the control signal from the monitor detector is arranged to control a level of an

19. An integrated, wavelength-stabilised laser source substantially as described and/or as illustrated in the accompanying drawings.

FIG 3



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(72) Inventors; and
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(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),

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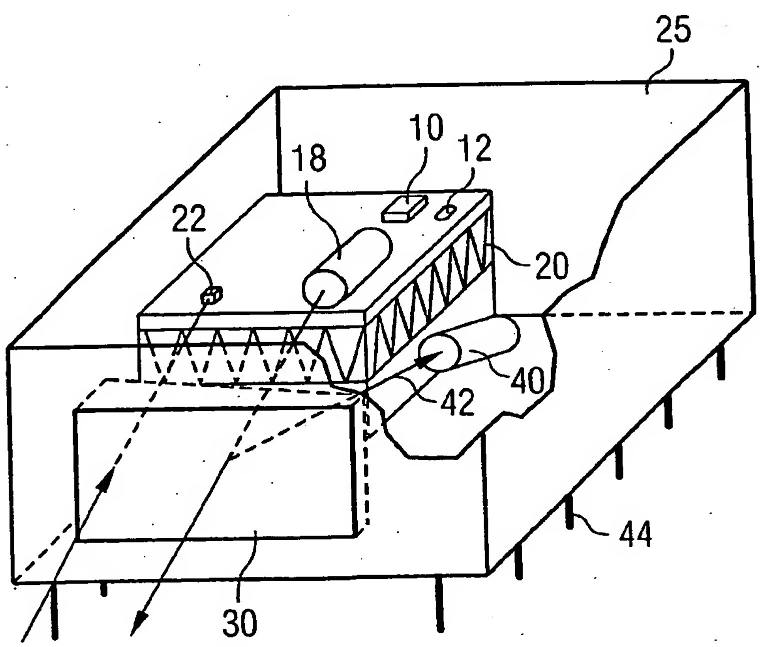
(54) Title: A WAVELENGTH STABLILISED LASER SOURCE



(57) Abstract: There is provided an integrated wavelength-stabilised laser source comprising: a laser diode; a temperature-stabilising heat pump in thermal communication with the laser diode; and at least one detector, encapsulated within a hermetically sealed package comprising a window for passing light from the laser diode to the exterior of the package.

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INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01S5/0687 H01S5/024 G01N21/39

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 403 243 A (HAKAMADA ISAO) 6 September 1983 (1983-09-06) abstract figure 2 column 2, line 5-38 ---	1
X	US 4 803 689 A (SHIBANUMA NAOKI) 7 February 1989 (1989-02-07) abstract figures 2A-2B ---	1
X	US 5 233 622 A (IWAMOTO KOJI) 3 August 1993 (1993-08-03) abstract figure 2A column 3, line 45 -column 4, line 16 ---	1
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 June 2003	23/06/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lendroit, S

INTERNATIONAL SEARCH REPORT

Intern: Application No
PCT/GB 02/00870

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LIQUID CONTACT SWITCH WITH AUXILIARY HEATING MEANS

Filed March 17, 1960 2 Sheets-Sheet 1

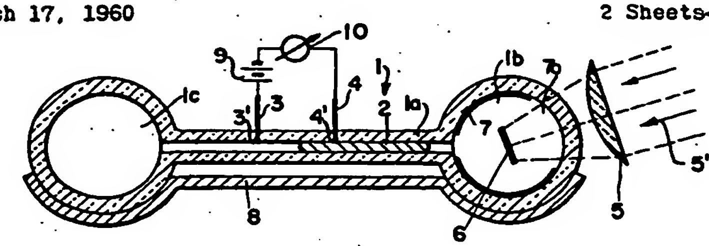


FIG.1.

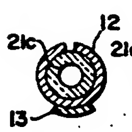
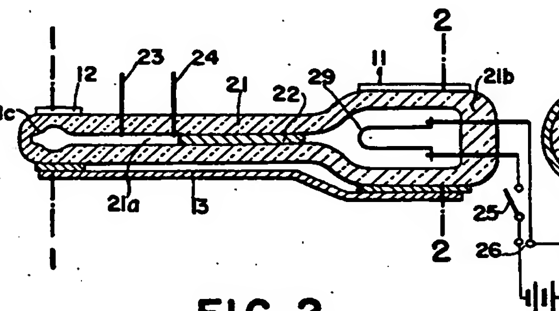


FIG.2a.



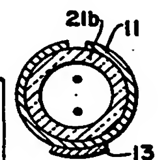


FIG.2b.

FIG.2.

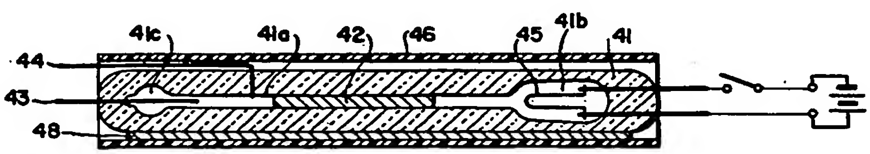
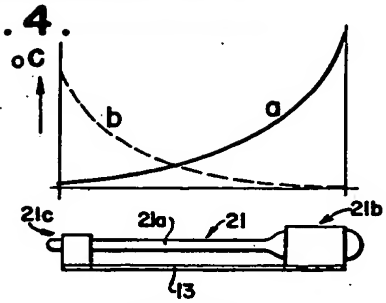


FIG.4.



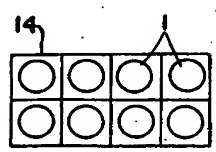


FIG.5.

FIG.3.

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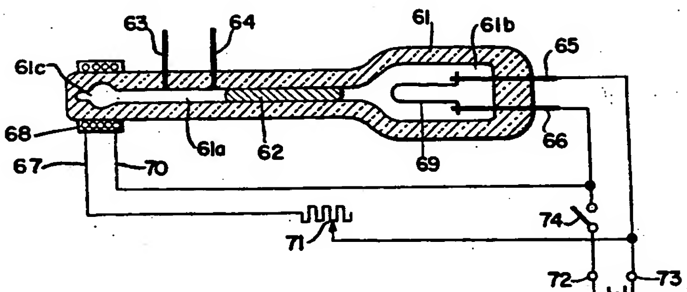
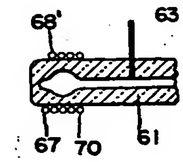
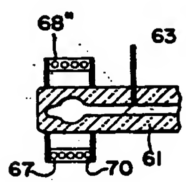


FIG. 6.





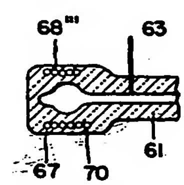


FIG. 7. FIG. 8. FIG. 9.

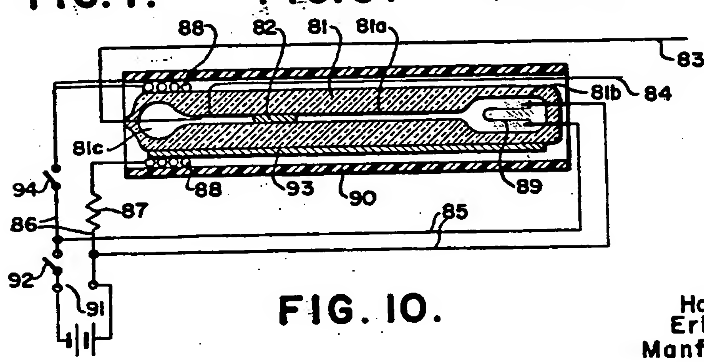


FIG. 10.

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